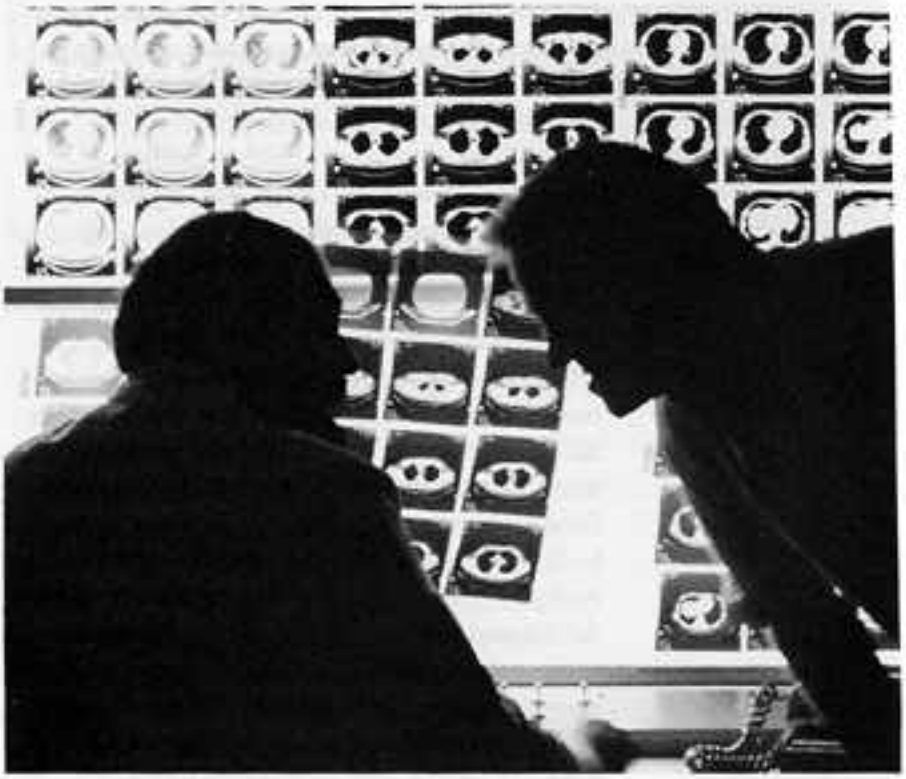
Domain 4:

Medical Informatics

Medical informatics attempts to provide the theoretical and scientific basis for the application of computer and automated information systems to biomedicine and health affairs. Inherently an interdisciplinary field, its practitioners and faculties currently come from the health professions, computer and information science, engineering, and management science.[45]

Medical informatics studies biomedical information, data, and knowledge—their storage, retrieval, and optimal use for problem-solving and decision making. It touches on all basic and applied fields in biomedical science and is closely tied to modern information technology, notably in the areas of computing and communication. The emergence of medical informatics as a new discipline is due in large part to advances in computing and communications technology, to an increasing awareness that the knowledge base of medicine is essentially unmanageable by traditional paper-based methods, and to a growing conviction that the process of expert decision making is as important to modern biomedicine as are the facts on which clinical decisions or research plans are made.[46]

Medical informatics is oriented toward the invention and dissemination of powerful information management tools. Those include frameworks for organizing and encoding medical knowledge, methods for acquiring and representing judgmental knowledge based on medical experience rather than formal studies, computer networks to permit efficient communication among health personnel, and systems to provide customized advice that give a practitioner access to expertise that might otherwise not be available when and where it is needed.



Processing information faster or more efficiently—which today's technology can easily accomplish—is not sufficient. More intelligent processing, logical aggregation of information, synthesis and analysis, and the development of knowledge systems that serve purposeful ends are needed. That is the fundamental task of medical informatics.

Goal 4.1:

Support Extramural Research on Information And Knowledge Structure In The Health Sciences

With funding and leadership provided by NIH and NLM, a community of researchers has been active for over two decades in wide-ranging applications of computers to medicine. This research has greatly advanced the capabilities of the computer as a research tool and medical decision support system and has laid the groundwork for the substantial work yet to be done. However, currently available funds for this purpose have left many highly rated research proposals approved, but unfunded.

In general, emphasis should be placed on research that examines fundamentally important issues and methodologies in the field, for example:

Cognitive Processes. Diagnosis, treatment, and management of disease can be viewed as a series of problems to be solved and decisions to be made—involving both clinicians and patients. Recent advances in experimental psychology and computer science have now made it possible to study complex mental processes of clinical decision making more rigorously than ever before imagined. New knowledge has been gained about how both expert and novice clinicians process, evaluate, and respond to clinical information. Additional research is needed to continue that work, especially as it pertains to the development of so-called "intelligent" computer systems designed to provide expert medical advice and decision support.

Medical Decision Making. Health care providers have a wealth of information available to them. The problem is picking from among the many options and making the right decision—the one that will result in the best treatment for the specific patient. Automated decision support systems that consider variables such as probable outcome, risk, cost efficiency, and patient satisfaction can be valuable tools for medical practitioners faced with hard choices. Further research into the development of such systems should address, among other things, decision making strategies; types and amount of clinical, experiential, and other data to be included; and factors influencing system acceptance and use by the medical community.

The Human-Machine Interface. Automated medical information systems ultimately involve a working relationship between a computer and a biomedical researcher or a medical decision maker. Interface research in medical informatics addresses that relationship, the interaction between human and machine. An interface mediates between the machine world (input/output devices, computer graphics, the mechanics of computer use) and the cognitive world (use modeling, natural language interaction, explanation.) Continued research into improving this connection is vital to ensuring that biomedical information users have the information they need, when they need it, in a form they can understand and use.

Knowledge Representation. Human beings and computers speak quite different languages when it comes to assimilating information. Each requires knowledge to be structured and depicted in specific ways before it can be processed and transmitted. Ideally, humans and computers should be able to function in their preferred states while communicating directly with each other at the same time. Ongoing research is required to identify a technology that can simultaneously translate between the two forms of biomedical knowledge representation.

Knowledge Acquisition. The central issue facing medical informatics today is how to structure and organize the vast amounts of knowledge being generated in biomedicine, how to store and retrieve that knowledge, and how to update and apply it—all in a timely, accurate, and cost-effective manner. A small number of true knowledge bases have been built manually through intensive interaction between subject matter experts and information system experts.[42,43,47,48] The first important steps have been taken with the development of automated methods for indexing and reorganizing knowledge bases.[49,50] Text understanding promises to speed up the process of knowledge acquisition for large, comprehensive knowledge bases.[51] Toward that end, a uniform system of medical terminology and language must be developed as well as standard formats for the collection and reporting of clinical and laboratory data.

Information Storage and Retrieval. If NLM's collection of biomedical literature were transferred to magnetic storage units today, over 4,000 disks would be required to contain it. And that does not include the enormous quantity of clinical and research data (images, instrument data, descriptions) generated each year. The problem for medical informatics is how to organize and structure this knowledge and retrieve it as needed in an efficient and cost effective fashion. As our knowledge continues to increase and computers come into more widespread use as information processers and managers, the problem can be expected to grow proportionately. What is needed are new approaches to the management of this information, especially more intelligent retrieval systems that will find information more discriminately.

Recommendations

4.1.1. Increase support of extramural research into knowledge structure and use in biomedicine and the health sciences.

4.1.2. Encourage research that addresses issues and methodologies of fundamental importance to medical information. Special emphasis research areas, NLM-sponsored conferences, program projects—all should be considered as possible mechanisms to achieve this goal.

4.1.3. Divide funding so that within five years each area of fundamental importance receives appropriate support.

Goal 4.2:
Strengthen Medical Informatics Research At NLM

In addition to its support of extramural research, NLM has devoted in-house resources, particularly from the Lister Hill National Center for Biomedical Communications, to research and development in medical informatics. A key activity is the development of the UMLS (Unified Medical Language System) recently initiated with special Congressional funding. When complete, the UMLS will provide a single logical path to the growing variety of machine-readable biomedical information.

The obstacle to progress in medicine presented by its bewildering and eclectic terminology has long been recognized; indeed, it has often been ridiculed. This problem is especially serious when combined with the linguistic shortcomings of existing automated information systems. Many lack knowledge even of misspellings and misstatements, pluralizations, common synonym forms, and standard abbreviations. The majority fail to understand the full contexts of queries, the use of colloquialisms, and technical jargon. All lack the human linguistic ability to understand homologies, metaphors, ellipses, and exemplars.

NLM's MeSH (Medical Subject Headings) thesaurus for cataloging and indexing the literature offers promise for the future, however. MeSH is systematic; it is controlled, yet evolves with changing times; and it has a responsible proprietor in NLM. Although MeSH was not designed to solve the linguistic problems of the biomedical field, it can serve as a starting point for UMLS.

The Unified Medical Language System project should be viewed as a major institutional initiative. This work should include fundamental research into methods for thesaurus construction, automatic linking of scientific and clinical vocabularies, methods for information retrieval in support of clinical decision-making and scientific discovery, and other appropriate basic and methodological research and development. The work should be conducted at NLM and in collaboration with appropriate scientific research and professional groups.

The Library should also continue its work on artificial intelligence systems for modeling medical expert decision making. Such systems, particularly in the fields of diagnosis and management, represent the current cutting edge of medical computer-science research. Rather than building the maximum number of expert systems, NLM's goal should be to remove obstacles from the creation and validation of such systems by the many relevant scientific and professional groups in the United States. Where possible, NLM should contribute as well to the evaluation of expert systems in real-world settings. The importance of this work will likely derive from the understanding it yields of fundamental processes rather than from its effect on the particular medical or scientific applications chosen for the experiments.

Having established automated systems for expert advice and decision support often proves less than satisfactory if their users must function in isolation. The inability of individual systems to communicate with one another is a frequently voiced problem reflected by complaints such as, 'the lab computer doesn't talk to the library computer.' To be most effective, automated information resources need to work together in ways that strengthen health care institutions and scientific collaboration.[52]

Excellent examples of partial solutions to this problem exist outside the health sciences. First, commercial computer time-sharing and electronic messaging systems and services already have met a warm reception from the business community. Even though the existing commercial systems lack features relevant to health care or biomedical research (privacy, large file transfer, data integrity, format conversions, image archiving, and high-resolution displays), they have already achieved much. For instance, they show that once the investment has been made to adopt electronic technology to business requirements, industrial and commercial processes are enhanced (made more economical and efficient) through electronic networking.

Recommendations

4.2.1 Continue development of the Unified Medical Language System by:

- Creating an internal research management team to participate in the research and to manage and coordinate extramural contributions.
- Providing for formal collaboration with appropriate extramural research groups.
- Establishing formal collaboration with appropriate medical and scientific professional associations.
- Announcing a special emphasis research grants program in areas relevant to the goals of the Unified Medical Language System. Seek to support up to eight investigator-initiated basic research projects at an average cost of $250,000 each.
- Reporting publicly on progress that enhances access to knowledge in the biomedical scientific literature.

4.2.2 Facilitate development and evaluation of expert systems by:

- Developing 2-6 expert systems at NLM.
- Encouraging strong interactions of these in-house research efforts with clinical collaborators as well as with appropriate extramural research teams.
- Seeking realistic test sites for one or more of these systems.
- Conducting research into methods of validating and evaluating the resulting systems.

4.2.3 Test a prototype national communications system for research in medical informatics by:

- Forming a management group within NLM focused on this experiment.
- Convening appropriate collaborative biomedical investigators and institutions from within the U.S.

- Providing a locus for discussion with private and industrial groups that might assist this development.
- Funding such developmental and evaluative work internally and extramurally as may legitimately contribute to testing the prototype.

4.2.4 Sponsor conferences, workshops, and symposia that advance thinking in domains of fundamental concern to the Library by:

- Strengthening existing arrangements to create or host regular public meetings.
- Creating a management system for choosing topics and schedules.
- Establishing a formal plan for such events to cover a two-year period, including a mechanism for evaluating the benefits and cost effectiveness of this strategy.

Goal 4.3:
Strengthen Competence In Medical Informatics in The Health Professions

The biomedical sciences and the health-care professions can best make use of current information services and the emerging advanced automated systems by becoming involved in their development and use. To play an active role and to choose wisely among possible developments will require a cadre of health professionals properly educated in medical informatics at a level sufficiently scholarly to match medical judgments with technical judgments.

Assistance is needed to strengthen the institutions that support such efforts. Departments, centers, and other academic units are needed to provide independent loci for scholarship and research at a number of selected institutions throughout the United States. Assistance is also needed to promote collaborative efforts among senior scholars in medical and computing fields.

The establishment of productive, stable centers of excellence conducting basic research and training in the fundamental problems of medical informatics is crucial to the growth of the field as a scientific discipline. This goal can be achieved only through commitment of national resources over a sustained period of time. The growth of the field, and of its potential contributions, has been impeded by past uncertainties of support. The field has also suffered from unrealistic expectations about the length of time needed to produce stable sources of basic support for top research and training institutions while permitting encouragement of focused centers in subareas of the medical informatics field.

An important goal for the Library for the next 10 years should be the establishment of centers of excellence in medical informatics at major academic health institutions. Each center of excellence should have a strong research emphasis and significant educational and training components. The centers should provide a leadership role in stimulating use of information technology and should develop a working relationship with the operational health-delivery system, practicing professionals from all health disciplines, and the health-science library community. The emphasis in all centers should be on academic activities.

There is also a growing need for research investigators in academic settings as well as in the rapidly enlarging medical informatics industry. Those who will seek to take their places as health-science faculty and to teach medical informatics in the professional and university setting must themselves have been qualified by appropriate pre- and post-doctoral education. Such special training is most easily provided by university-based research training projects with the appropriate special focus. Already supported in small numbers by NLM, such projects should be increased.

The Library should seek additional resources in order to expand its successful grant program for training in medical informatics. The training offered should be academic in character; support for vocational training should be sought from other sources. Training ought also to be offered at the Library on a short term basis or as an 'in-house' sabbatical for an academic year.

Recommendations

4.3.1. Strengthen institutional development of medical informatics within universities by:

- Initiating six centers of excellence in medical informatics as soon as possible through a competitive extramural grants program that would assure a minimum of five years support to grantees.
- Encouraging ongoing applications for center grants until there are 15 active centers at the end of 10 years.

4.3.2 Support research training and research career development for individuals in medical informatics by:

- Increasing immediately the number of NLM training programs in medical informatics from five to ten institutions.
- Gradually increasing the number of training grants, by an increment of approximately one per year, until 20 institutions are receiving support at the end of the next decade.
- Expanding support for young investigators through current programs for New Investigator Awards, and Research Career Development Awards.

4.3.3 Strengthen collaboration and scholarship at NLM by:

- Introducing a formal visiting scholar program that would bring medical informatics investigators and trainees to the Library for periods of 3, 6, or 12 months.
- Establishing stipends to support sabbaticals at NLM for up to five mid-career professionals.

Budget

Estimates of resources needed to implement these recommendations are given in Chapter 4.